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DECEMBER 1972

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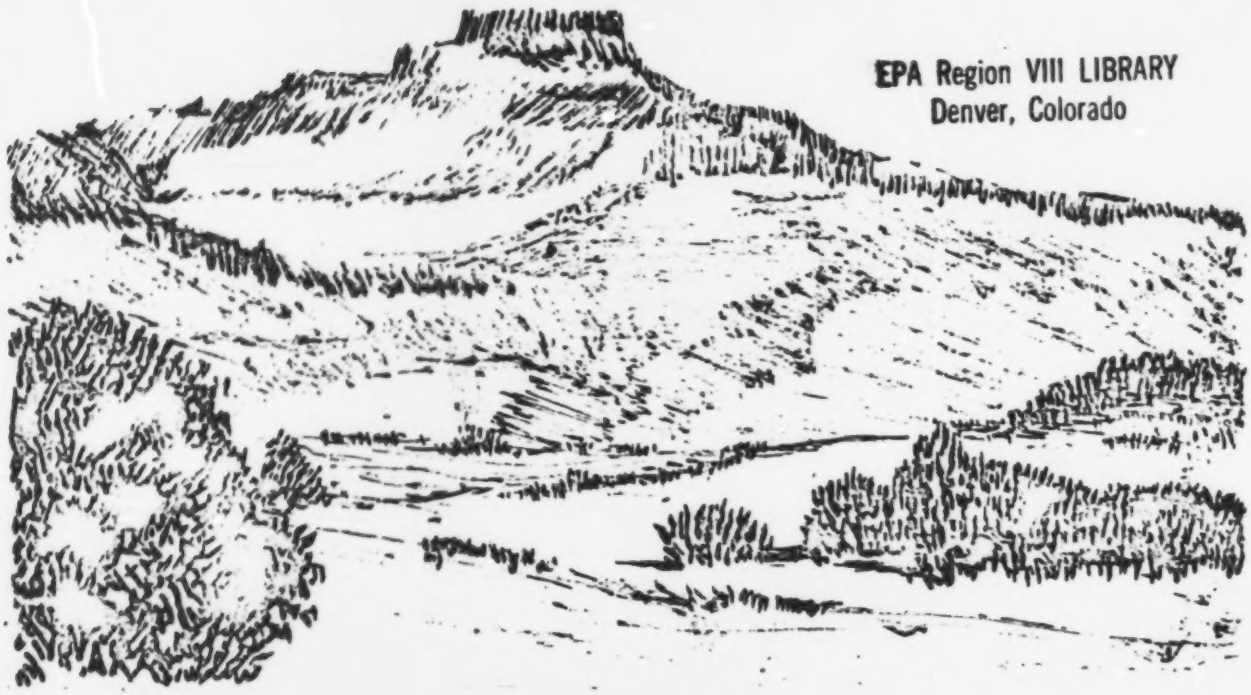
TECHNICAL ASSISTANCE PROJECT
TRINIDAD WASTEWATER TREATMENT FACILITY
TRINIDAD, COLORADO

SEPTEMBER, 1972



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At the request of the city of Trinidad, technical assistance was provided in operation of a wastewater treatment facility. Control tests were initiated to enable the operators to manage plant operations so to achieve the best possible effluent with facilities available. Limitations which hindered plant operation and performance were identified and evaluated. Recommendations concerning these limitations were made. Since major plant modifications appear to be necessary, it is suggested that a thourough engineering study be undertaken to determine alternative measures.

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ABSTRACT

At the request of the City of Trinidad technical assistance was provided by the Environmental Protection Agency concerning the operation of their Wastewater Treatment Facility.

Control tests were initiated to enable the operators to control plant operations to achieve the best possible effluent with facilities available.

Limitations which hindered plant operation and performance were identified and evaluated. The major limitations were the lack of an adequate oxygen supply to the aeration basins and aerobic digester, and lack of adequate aerobic digester sludge detention time (i.e. size). The quantity of oxygen supplied to the aeration basins and aerobic digester was determined to be approximately one-half the quantity required. The size of the aerobic digester was determined to be approximately one-third the required size at the present plant flow of 1 million gallons per day (MGD) and one-fifth the required size at the design plant flow of 1.5 MGD. Other limitations which hindered plant operations were identified and are discussed in the report. Recommendations concerning these limitations were made.

Since major plant modifications appear to be necessary all alternative methods to achieve satisfactory plant operation and performance should be considered. It is suggested that a thorough engineering study be undertaken to determine these alternative measures.

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I. INTRODUCTION

On April 6 and 7, 1972, a brief operation and maintenance survey of the Trinidad Wastewater Treatment Facility was made by engineers from Region VIII of the Environmental Protection Agency in response to reports of difficulties with sludge digestion. In the initial visit it was determined that the existing laboratory facilities at the plant were not sufficient to make a detailed analysis of the problem. A subsequent visit was made by an EPA chemist with special analytical equipment. Based on these visits recommendations were made concerning the operation of the facility. Plant features which apparently inhibited proper operation were also noted.

Problems with improper sludge digestion and other operational difficulties continued into the summer months. On July 21, 1972, EPA received a request for assistance from the City of Trinidad to develop better analytical capabilities for closer monitoring and control of wastewater treatment operations. A technical assistance project was initiated on September 18, 1972.

II. PURPOSE AND SCOPE

The purpose of this report is to summarize the results and findings of the technical assistance project conducted at the Trinidad, Colorado Wastewater Treatment Facility.

The initial objective to develop better analytical capabilities for closer monitoring and control of wastewater treatment operations was successful to a degree and is documented in this report. In addition, those portions of the plant which limited improvement of effluent quality or hindered operation of the sludge digestion unit were identified, evaluated, and are discussed in the report.

III. DESCRIPTION OF PLANT

A. BACKGROUND

Prior to August 1971, the Trinidad Wastewater Treatment Facility consisted of an Imhoff tank and sludge drying beds. In August 1971, a new activated sludge plant was put on line. In addition, a lift station was constructed to bring sewage from the "south" section of the city to the new treatment facility.

Design flow for the activated sludge plant is 1.5 million gallons per day (MGD). Present flow consist primarily of domestic wastewater. During assistance the average plant flow was approximately 1.0 MGD.

B. PLANT FACILITIES

Figure 1 shows the plant flow schematic for the Trinidad facility and Table 1 indicates the size of the various units. A brief discussion of each unit and its interrelationship with other units is outlined below.

Flow from the "north" and "south" sections of the city enters the plant through an inlet structure, and is directed through a grit channel, comminutor, and Parshall flume. The grit channel and comminutor may be bypassed by diverting the plant flow through a bar screen and then to the Parshall flume. Grit is collected and hauled to the original sludge drying beds for burial. The inlet Parshall flume is not used for flow measurement since extreme variations in plant flow occur as the lift station pumps cycle on and off. Plant flow is automatically recorded from readings taken at the Cippoletti weir located at the discharge from the chlorine contact basin.

After raw sewage passes through the Parshall flume it combine with return sludge from the final clarifier and is directed to the aeration basins. No primary treatment facilities are provided at Trinidad. After aeration, flow is directed to the final clarifier, then to the chlorine contact basin, and is discharged to the Purgatoire River. Sludge collected in the final clarifier is returned to the head of the aeration basins by two constant speed centrifugal pumps. The clarifier is equipped with a conventional type scraper mechanism and scum removal facilities. Return sludge flow rate may be adjusted by using either one or two return sludge pumps and by opening or closing a plug valve located on the pump discharge line. Return sludge flow is measured with a 10-inch proportional weir.

Sludge is wasted by partially closing a gate valve located near the head end of the aeration basins thus forcing a portion of the return sludge into the aerobic digester. Waste sludge flow is measured with a 4-inch proportional weir.

The aerobic digester has seven hopper compartments approximately 14 feet deep. The distance from the top of the hoppers up to the liquid surface in the digester is about 7 1/2 feet. A wooden partition between the 6th and 7th compartment is used to provide a quiscent zone in the 7th compartment for solids, liquid separation. A slot in the partition allows sludge to flow into the 7th compartment. Air is shut off in the 7th compartment about 12 hours per day and sludge is allowed to decant. Supernatant is displaced from the 7th compartment as the incoming waste sludge raises the liquid level in the digester. Supernatant is forced over an effluent weir and back to the head end of the aeration basins.

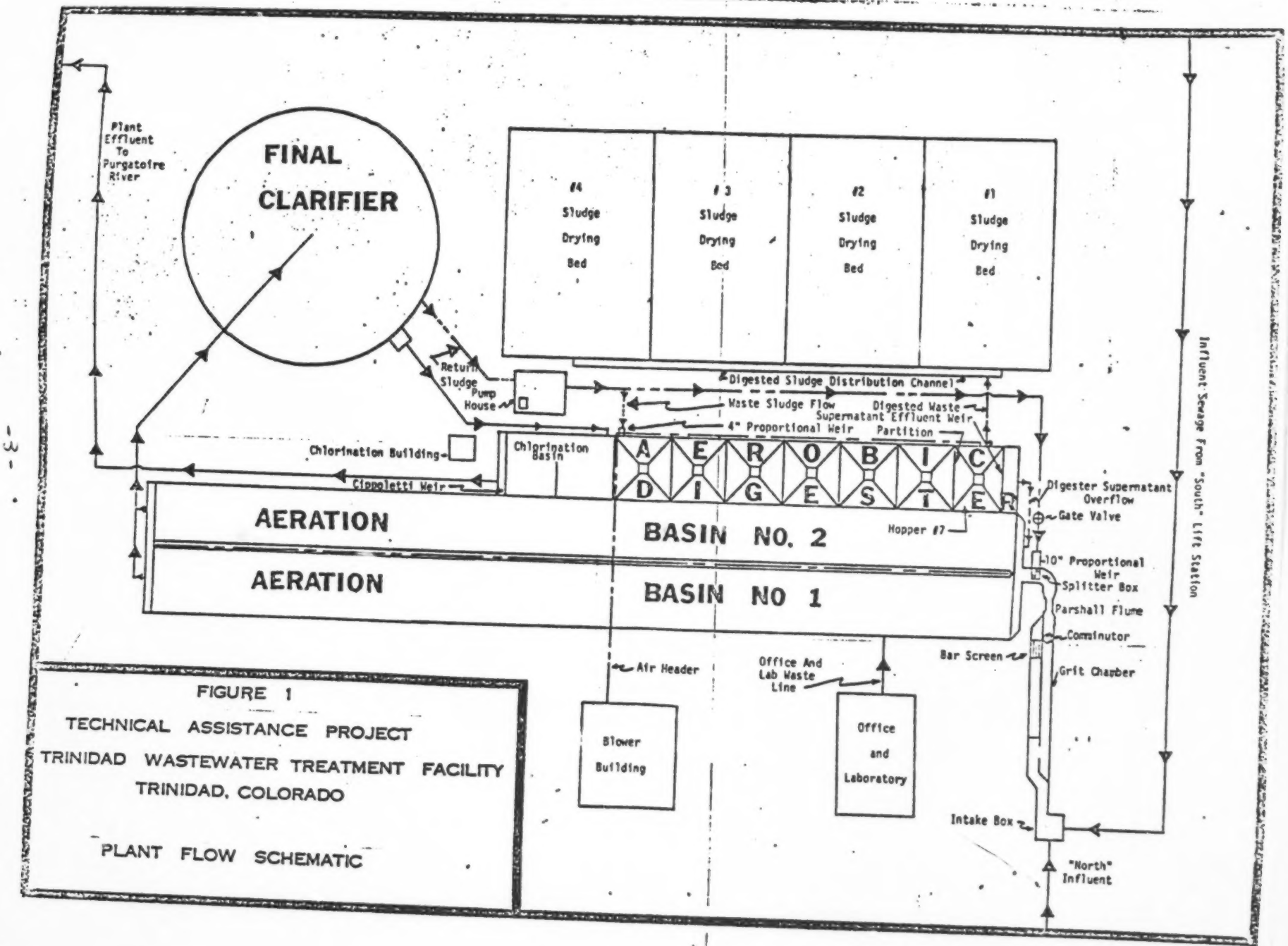

FIGURE 1

TECHNICAL ASSISTANCE PROJECT

TRINIDAD WASTEWATER TREATMENT FACILITY

TRINIDAD, COLORADO

PLANT FLOW SCHEMATIC

TABLE I

FEDERAL ASSISTANCE PROJECT
TRINIDAD WASTEWATER TREATMENT PLANT
SEPTEMBER 18-28, 1972

PLANT UNIT SIZES

UNIT	NUMBER	UNIT SIZE
Aeration Basin	2	307,500 gallons/basin
Aerobic Digester	7 compartments	16,000 gals/compartments
Drying Bed	4	35 ft x 60 ft/bed
Air Compressor (Aeration Basin)	2	1200 cfm/compressor
Air Compressor (Aerobic Digester)	1	400 cfm/compressor
Air Compressor (Standby)	1	1200 cfm/compressor
Clarifier	1	65 ft Dia--209,000 gals.
Return Sludge Pump (Centrifugal)	2	300 gpm at 20 ft. TDH 520 gpm at 10 ft. TDH
Sludge Pump (Diaphram)	1	35gpm*

*Determined from a series of tests conducted during assistance

Prior to assistance several difficulties were affecting the operation of the solids liquid separation. First, only a limited amount of air could be provided in the 7th compartment because the turbulence caused by the air would force solids over the digester effluent weir and back into the aeration system. The other problem was caused by excessive amounts of scum that accumulated on the seventh hopper during quiscent periods. This scum was carried over with the supernatant and was recycled to the head of the aeration basins. To limit the quantity of solids carried over due to turbulence when the valve regulating the air flow to the 7th compartment was fully opened, a removable baffle ("2 x 6" board) was placed against the weir during periods of aeration. The scum problem was solved by wedging a "2 x 4" board about 8" in front of the effluent weir to act as a scum baffle. Settled sludge is pumped from the hopper in the 7th compartment to one of the 4 sludge drying beds or distributed over the land. A diaphram pump is used to remove digested solids from the aerobic digester.

Two 1200 cfm centrifugal blowers are used to supply air to the aeration basins. One hundred and fifty-two course bubble diffusors are spaced so as to create a "spiral flow" pattern in each of the aeration basins. Each diffusor has twelve openings approximately 1/8-inch in diameter. The number of openings per diffusor may be adjusted to either 4, 8, or 12 holes.

A 400 cfm centrifugal blower is used to supply air to the aerobic digester. Each of the seven hoppers of the digester has three course bubble diffusors located at the bottom of each hopper. The diffusors are identical to those found in the aeration basins. A 1200 cfm blower is provided for standby. Piping limitations will not allow all four blowers to operate at the same time.

IV. SUMMARY OF ASSISTANCE PROJECT

A. SUMMARY OF LABORATORY ASSISTANCE

Prior to the assistance project plant personnel periodically performed monitoring analysis. Biochemical oxygen demand (BOD_5) analysis were performed on wastewater grab samples. The methodology used was one outlined by a chemical supply company and required the company's specific glassware and reagents. Total solids analyses had been performed on one occasion on sludge samples. Dissolved oxygen measurements were performed on mixed liquor samples using the azide modification as listed in Standard Methods for the Examination of Water and Wastewater 13th Ed. This method is not satisfactory for mixed liquor samples because of the high mixed liquor suspended solids (MLSS) concentrations. However, this method can be used on wastewater samples that do not contain chlorine or high suspended solids concentrations.

During assistance appropriate instruction was given to allow plant operators to routinely perform specific monitoring analysis. The laboratory had been equipped with the glassware and reagents necessary to determine the BOD_5 analysis using the methodology listed in Standard Methods and the solids analysis using the methodology listed in the EPA's Methods for Chemical Analysis of Water and Wastes 1971. The operators were taught the proper techniques used in collecting and storing composited samples of influent and effluent wastewater. However, since plant influent flow was not measured, no attempt was made to collect the composited samples proportional to flow. The operators were instructed on the procedures used in preparing dilution water and setting up BOD's utilizing the cylinder dilution technique. The dissolved oxygen concentration of each BOD dilution was determined using the azide modification of the Dissolved Oxygen Method, using proprietary reagents. Additionally, the operators were taught the proper techniques used in performing the total and volatile suspended solids tests on wastewater, mixed liquor, and sludge samples utilizing gooch crucibles and glass fiber filters.

Just prior to the assistance project the City of Trinidad had purchased a YSI Model 51A Dissolved Oxygen Meter and Probe. During assistance the operators were taught how to calibrate the instrument and how to adjust it when measuring the dissolved oxygen concentration in the aeration basins or the aerobic digester.

As a result of the laboratory assistance project, personnel at the Trinidad Wastewater Treatment Plant are routinely collecting and storing wastewater samples and are analyzing these samples for BOD_5 and suspended solids concentration using approved methods of analysis. They are also capable of performing a variety of solids analysis on mixed liquor and sludge samples. In addition, the

dissolved oxygen concentration can now be measured on the mixed liquor in the aeration basin and sludge in the aerobic digester using the dissolved oxygen meter and probe.

B. SUMMARY OF OPERATIONAL ASSISTANCE

1. Plant Testing

In addition to instruction in conducting various laboratory analysis, plant personnel were given instruction in conducting and interpreting various "control" tests. Dissolved oxygen tests, centrifuge tests, turbidity, settleability tests, and sludge blanket depth were the control tests that were initiated. These tests were conducted three times per day seven days a week during the project.

Dissolved oxygen (D.O.) tests were used to monitor the availability of dissolved oxygen in the plant. The most critical points for the availability of D.O. were determined by taking D.O. measurements throughout the length of the aeration basin and aerobic digester. D.O. measurements were routinely taken at the head end of each aeration basin and at the head end of the aerobic digester.

Centrifuge tests were used to determine variations in solids concentrations from day-to-day. Tests were conducted on samples of mixed liquor taken at the discharge end of each aeration basin, on samples of return sludge, on samples of sludge in the aerobic digester, and on samples of sludge wasted to the drying beds. The centrifuge values are expressed in percent solids by volume. Although it is not necessary for control, a correlation between percent solids by volume and solids by weight was made. The results of this correlation indicated that during the project one percent by volume was approximately equal to 870 mg/l by weight. This correlation will vary as the characteristics of the sludge vary. For this report all solids concentrations by weight were determined by using the correlation of one percent by volume equal to 870 mg/l by weight.

Turbidity tests were performed on samples of the effluent from the final clarifier. Test results were used to monitor the performance of the activated sludge process prior to obtaining a BOD_5 result.

Settleability tests were conducted on samples of the mixed liquor collected at the discharge end of the aeration basins. Settleability tests were used to monitor and observe sludge settling characteristics.

Sludge blanket depth determinations were made on the final clarifier. Results were used to monitor changes in the depth of the blanket and to determine the amount of sludge that was

accumulating in the final clarifier.

Data obtained from the various control tests were used to perform calculations and develop various graphs. The graphs were used to interpret plant performance and control plant operations.

Trinidad owned most of the control equipment mentioned above and is continuing to use the tests, calculations, and graphs to control their operations.

2. Plant Operation

Initiation of the control tests, corresponding data interpretation, and methods used to control plant operation pointed out various operational procedures that should be followed. A discussion of all areas of plant operation would be too lengthy for this report. Only those areas which limited control flexibility or hindered operation and maintenance are discussed.

A maintenance problem is encountered when trying to service the comminutor. The operator can divert sewage through a bar screen and bypass the grit channel and comminutor when the latter two units require repair or maintenance. However, diverted sewage reenters the main channel directly behind the comminutor thereby flooding the area the operator would have to work in to repair the comminutor. A special gate to block the sewage from entering this working area or a different by-passing arrangement will have to be constructed before the operator can service or repair the comminutor.

An operational problem that is encountered is one of uneven solids distribution between the aeration basins. Return sludge flow enters the main sewage channel and mixes with the sewage just before the combined flow splits and enters the two aeration basins. Adequate time for complete mixing is not provided and often the solids concentration in the two aeration basins is not equal. To compensate for this problem, plant personnel placed an adjustable splitter box between the return sludge stream and the sewage stream in order to provide better mixing conditions and balance the MLSS concentration in the two aeration basins. The adjustable splitter box served to alleviate some of the problem. However, difficulties in balancing the MLSS concentration in the aeration basins are still encountered when return sludge flow rates are varied. When these rates are varied, the splitter box must be adjusted. The adjustment requires a trial and error procedure and is not responsive enough to obtain the desired, balanced MLSS concentration. Modifications should be made to the return sludge flow piping to either introduce return sludge upstream in the aeration basin inlet channel to insure that mixing is completed before the combined flow enters the aeration basins or introduce return sludge separately and equally to each aeration basin.

Another operational problem is one of convenient return sludge flow measuring and control. Prior to assistance operators controlled return sludge flow by opening and closing a gate valve located near the inlet ot the aeration basins. Rags and other debris in the return sludge clogged the opening in the gate valve when the valve was partially closed. To prevent clogging, the gate valve had been opened wide enough to pass the rags and a constant return sludge flow rate had been established and was maintained.

During assistance return sludge flow rate was varied by opening and closing a plug valve located in the return sludge pump house. No problems with clogging occurred. However, due to the location of the plug valve two to three men were required to adjust the return flow to a given rate. One man was required to measure the flow rate at the 10-inch proportional weir and signal a second man located at the opening to the underground return sludge pump house (See Figure 1 for location of these units). The second man could then signal a third man located in the pump house, who would either open or close the plug valve according to the instructions.

A man could be eliminated from this control procedure if a hole was drilled in the roof of the pump house to allow use of a long stem rod to open or close the plug valve. A more feasible solution would be to locate a plug valve or butterfly valve near the present return sludge flow measuring weir which is located near the inlet to the aeration basins. Locating the plug valve near the weir would allow the operator easy access to both the flow measuring and flow control devices. The addition of this new valve could be accomplished at the same time the return sludge flow piping is modified. (Return sludge flow piping modification were recommended to insure proper distribution of solids between the aeration basins.)

A problem was also encountered with the proportional weir that is used to measure flow to the aerobic digester. The actual flow through the weir was not equal to the flow rate obtained from the weir table. A series of tests were conducted to determine the accuracy of this four-inch proportional weir. First the liquid level in the aerobic digester was lowered by disposing sludge to the drying beds. Activated sludge was then wasted to the aerobic digester through the four-inch proportional weir at a constant gauge depth of 0.2 feet. The time required to fill the displaced volume of the digester was recorded and a flow rate was calculated. Test results indicated a flow rate of 78gpm at a gauge depth of 0.2 feet whereas the flow table for this weir indicated that the flow should have been 60gpm at 0.2 feet. It may be expected that the actual flow rate through the proportional weir that is used to measure return sludge flow is not equal to the flow rate obtained from its' weir table also.

In most plants a proportional weir is used to control the velocity of flow in the channel upstream from the weir. In fact, a proportional weir is used for this purpose in the grit chamber at Trinidad. Devices that have been used to measure sludge flows in other plants include V-notch weirs, rectangular weirs, in-line flow meters, Parshall flumes, etc. Although day-to-day comparisons can be made using the existing proportional weirs for flow measurement, it is suggested that consideration be given to installing more accurate flow measuring devices.

No flexibility for activated sludge process variations has been provided at the Trinidad facility. However, it appears that with minor modifications the capability of "step loading" sewage to the aeration basins may be incorporated. Step loading has the advantages of providing a more even distribution of oxygen requirements throughout the entire length of the aeration basin and of allowing a higher mean MLSS concentration for a given solids loading to the clarifier. The minor modifications that may allow the step loading capability are: using the center channel located between the two aeration basins as a distribution channel and locating gates along this channel for sewage distribution to the aeration basins. It appears that adequate head is available in the pre-treatment structure to allow using the channel between the aeration basins. These modifications, if feasible, would provide the operator with one more alternative of operation that would aid him in operating his plant to consistently produce the best possible effluent under changing conditions.

Another area of operational difficulty which was significant in hindering plant operation and control was the air supply to the aeration basins. During the survey the mixed liquor dissolved oxygen concentration never reached 1 mg/l and was usually less than 0.5 mg/l. This low D.O. concentration hindered the performance of the activated sludge process. To insure that the aeration system was providing maximum oxygen transfer the diffusors were removed and inspected. It was found that an estimated 20% of the diffusor openings were clogged. A program was initiated to clean all diffusors in the aeration basins as soon as possible. At the termination of the assistance project approximately one-half of the diffusors in the aeration basins had been cleaned. Cleaning these diffusors did not measurably increase the D.O. concentration even in the area where the diffusors were cleaned. Since the termination of the assistance project all diffusors in the aeration basins have been cleaned. It is recommended that all diffusors in the aeration basin and aerobic digester be put on a routine maintenance schedule and cleaned a minimum of three times per year.

In a further effort to increase D.O. concentration, an attempt was made to increase the air flow to the aeration basins. Normally

two 1200 cfm air compressors are used to provide air to the two aeration basins. One 400 cfm air compressor is used to provide air to the aerobic digester. One additional 1200 cfm air compressor is on standby. Before all diffusors were cleaned an attempt was made to use the three 1200 cfm air compressors to force air to the aeration basins and the aerobic digester. However, when all three 1200 cfm air compressors were on, back pressure in the system caused the safety pressure relief valves to open. After assistance all the diffusors in the aeration basins were cleaned and all 12 holes were opened on each diffusor. This time a successful attempt was made to use all three 1200 cfm air compressors. The D.O. concentration in the aeration basins and aerobic digester, however, did not increase significantly. Apparently the increase in air flow did not supply enough oxygen to completely satisfy the high oxygen demand of the solids in the aeration basin or aerobic digester.

In an even further effort to increase D.O. concentration in the aeration basin, steps were taken to decrease the MLSS concentration (during assistance average MLSS was 5,700 mg/l). A lower MLSS normally has as lower oxygen demand. Solids were wasted to the aerobic digester to attempt to decrease MLSS concentration. Each day the 7th compartment of the digester was allowed to settle for about 12 hours and activated sludge was then wasted to the digester. Supernatant was displaced and recycled to the head of the aeration basins until such time as sludge solids began flushing over the weir with the supernatant liquor. Approximately 4,000 gallons of activated sludge could be wasted until solids began to carry over. Wasting of activated sludge was then temporarily stopped and digested sludge was pumped from the bottom of the 7th hopper to a drying bed. After the digester was drawn down wasting was started and continued until the digester was refilled to its original level. The total average volume of sludge that could be wasted from the activated sludge system each day was approximately 8,500 to 9,500 gallons.

It is noted that wet sludge wasted to the sludge drying bed was pumped to a tank truck and hauled to a land disposal site. The tank truck was capable of hauling 4500 to 5500 gallons of wet sludge each day. The three other drying beds were not available for sludge disposal since two were full of wet sludge and the sand and gravel base was being replaced in the third bed.

The quantity of sludge wasted from the activated sludge system is a function of the number of gallons wasted and the solids concentration of the wasted sludge. Each time sludge was wasted the waste sludge solids concentration was determined by centrifuge and the volume of sludge that was recorded. Solids concentration by centrifuge was multiplied by volume wasted and the product was called waste sludge units (W.S.U.). W.S.U. represented that quantity of sludge intentionally wasted from the system.

Total quantity of sludge wasted from the activated sludge system includes that intentionally wasted and that unintentionally wasted or those solids lost in the effluent. At Trinidad the unintentionally wasted solids represented a small portion of the total solids wasted since effluent suspended solids concentrations were low (less than 25 mg/l).

Daily, values of mixed liquor concentration, waste sludge units, and depth of sludge blanket in the final clarifier were plotted versus time. It was found that wasting the maximum amount of gallons of sludge each day (8500-9500 gallons) did not decrease the mixed liquor solids concentration or the clarifier blanket depth. In fact, mixed liquor concentrations increased slightly. This indicated that daily wasting was not quite adequate to handle the quantity of sludge that was produced each day.

An attempt was made to increase the waste sludge concentration of solids to make the wasting more effective (i.e. more solids wasted with the same volume of flow). This was done by decreasing the return sludge flow as the plant flow increased allowing solids to accumulate in the final clarifier. The solids which accumulated in the final clarifier had more time to thicken, thus the underflow concentration was increased and the concentration of solids wasted to the aerobic digester increased. This method of wasting allowed greater quantities of sludge to be removed from the system but still did not enable a significant decrease in mixed liquor solids concentration to occur. This experience showed that even with plant operation distorted (i.e. normally return sludge flow should increase when plant flow increases) plant limitations would not allow optimum operating conditions or performance to be achieved.

Another factor which influences plant operation is manpower requirements versus manpower supply. During assistance Trinidad used three operators to operate and maintain the plant as well as perform the laboratory analysis necessary to monitor plant performance. An operator was at the plant 16 hours per day (8 hour shifts), 7 days per week. All three operators have comparable training and no specific operator was in charge of the entire plant operation. It is recommended that a separate laboratory technician be used 5 days per week to perform the laboratory analysis necessary to monitor plant performance. The plant operators may be used to perform the monitoring analysis to a limited degree during the weekend. The use of a separate laboratory technician would allow plant operators to concentrate on plant operation and maintenance. Secondly, it is recommended that a chief operator working on the plant site be appointed. The appointment of a chief operator would insure that all plant operation and maintenance activities are properly scheduled and performed. In addition the chief operator could decide on a given mode of plant operation and then direct plant activities

to properly monitor the effects of the change in this mode of operation. In so doing it would be possible to identify the mode of operation which yields consistently the best possible effluent.

3. Plant Evaluation

Plant effluent quality was generally satisfactory. During assistance the average effluent BOD_5 and TSS concentrations were approximately 20 mg/l. However, it is felt that these BOD_5 and TSS concentrations could be significantly decreased if specific plant limitations are overcome. The primary factor limiting ideal plant performance was unsatisfactory sludge digestion which inhibited solids control. A complete analysis of the operation and design of Trinidad's aerobic digester is discussed later in this report.

Another factor which limited improved plant performance was the air supply to the aeration basins. During the survey the mixed liquor D.O. concentration never reached 1 mg/l and was usually less than 0.5 mg/l. The results of a detailed study analyzing the air supply to the aeration basins is discussed later in this report.

V. UNIT ANALYSIS

A. AERATION BASIN

Because of the apparent limitations observed concerning the aeration basin at Trinidad special analyses were made. These analyses of the performance of the aeration basins consisted of determining the transfer efficiency of the course bubble diffusors and the limitations of the aeration equipment. This section of the report discusses the procedures used in the analysis and the results of the special studies.

The performance of an activated sludge plant depends to a large extent on the performance and capabilities of the aeration system. At Trinidad the actual quantity of oxygen supplied to the mixed liquor in the aeration basins was determined by expanding the relationship between the dissolved oxygen concentration and the rate of oxygen consumption (1). The relationship may be expressed by the following Equation 1:

$$dC/dt = K_L a(C_S - C) - r_r \quad \text{.....1}$$

where;

dC/dt = rate of change of dissolved oxygen concentration (mg/l/hr)
$K_L a(C_S - C)$ = rate of supply of dissolved oxygen (mg/l/hr)
r_r = rate of oxygen consumption of mixed liquor (mg/l/hr)
C = dissolved oxygen concentration in mixed liquor (mg/l)

C_s = saturation dissolved oxygen concentration in mixed liquor (mg/l)
t = time, and
K_La = overall oxygen transfer coefficient (mg/l/hr/unit concentration gradient)

At steady state the rate of change of dissolved oxygen concentration approaches zero and Equation 1 becomes:

$$r_r = K_La(C_s - C) \quad \ldots\ldots 2$$

and,

$$C = C_s - (1/K_La)(r_r) \quad \ldots\ldots 3$$

According to Equation 3 a plot of C vs. r_r produces a straight line with a slope equal to $1/K_La$ and y-intercept equal to C_s. To determine C_s and $1/K_La$ it is necessary to make simultaneous determinations of C and r_r at various mixed liquor dissolved oxygen concentrations. The load to the aeration tank must be varied, but must be within the capacity of the aeration equipment. Additionally conditions approaching steady state must be maintained.

Under existing operating conditions at Trinidad the mixed liquor D.O. concentration was generally less than 0.5 mg/l which is less than normally allowed for accurate test results. At these low values it is felt that oxygen is a limiting factor and steady state conditions cannot be achieved. In order to reach a D.O. concentration greater than 0.5 mg/l, flow to the #1 aeration basin was reduced. D.O. concentrations were allowed to increase until near steady state conditions were achieved. All diffusors in the test area were cleaned prior to collection of test data.

Ten different sets of test data were taken at various times and at various D.O. concentrations throughout the test period. Test data included aeration basin mixed liquor D.O. concentration, temperature, and oxygen uptake rate. Mixed liquor D.O. concentration and temperature were measured with a polarographic probe connected to a dissolved oxygen meter. At the same time and at the same location that the D.O. and temperature tests were run, a sample of mixed liquor was collected for determining the oxygen uptake rate. Results of these determinations are shown in Table 2.

To determine the oxygen uptake rate the mixed liquor sample was aerated with pure oxygen for approximately 3-5 seconds and transferred to a standard BOD bottle. The BOD bottle was placed in a water bath to maintain a constant sample temperature and then placed on a magnetic stirrer to insure that the sample was completely mixed while the D.O. concentration was measured. Sample D.O. concentrations were measured at one minute intervals with a polarographic

TABLE 2

TECHNICAL ASSISTANCE PROJECT :
TRINIDAD WASTEWATER TREATMENT FACILITY
TRINIDAD, COLORADO

MIXED LIQUOR OXYGEN UPTAKE RATES AND DISSOLVED OXYGEN CONCENTRATION
DURING CONTROLLED TESTING PERIOD

Sample No.	Date	Time	Temperature °C	Dissolved Oxygen mg/l	Oxygen Uptake Rate mg/l/hr
1	9/24/72	11:00 a.m.	20.2	1.05	22.1
2	"	11:25 a.m.	20.7	1.30	18.8
3	"	12:00 a.m.	20.5	0.80	24.8
4	"	1:40 p.m.	20.5	1.20	22.0
5	"	3:30 p.m.	20.7	1.45	19.0
6	9/25/72	6:15 a.m.	20.0	2.70	17.9
7	"	6:50 a.m.	20.1	3.05	22.0
8	"	7:25 a.m.	20.0	2.00	18.4
9	"	9:35 a.m.	20.0	0.50	26.0
10	"	1:25 p.m.	20.5	1.90	22.4

NOTE: 1. All samples were collected in the portion of Aeration Basin #1 in which all diffusors had been cleaned.

probe and built-in stirrer connected to a dissolved oxygen meter. Using the water bath the temperature of the sample during the test was kept as close as possible to the collection temperature. The resulting D.O. concentrations were plotted versus time on standard graph paper and the slope of the line or oxygen uptake rate was determined.

Figure 2 shows the relationship between aeration basin mixed liquor D.O. concentration and the corresponding oxygen uptake rates determined from the various samples. A linear regression analysis of the data indicated that $1/K_La$ equaled - 0.163 hr (or K_La equals 6.14 hr^{-1}) and C_s equals 5.1 mg/l. The solubility of oxygen in pure water at a temperature of 20.5°C and altitude of 6,000 feet above sea level is 7.25 mg/l. The difference in C_s (5.1 mg/l) and the oxygen solubility in pure water (7.26 mg/l) may be due to the effects of dissolved and suspended solids in the mixed liquor.

Aeration basin mixed liquor D.O. concentration is a function of the actual rate at which oxygen is supplied to the mixed liquor and the rate at which oxygen is utilized by the microorganisms. Theoretically at a D.O. concentration equal to 0.0 mg/l, the actual rate of oxygen supplied to the mixed liquor is equal to the rate at which the oxygen is utilized. Using this approach the rate of oxygen supply at Trinidad can be determined as that rate corresponding to a D.O. concentration of 0.0 mg/l. From Figure 2 the rate of oxygen supply was determined to be 31.1 mg/l/hr.

The aeration equipment oxygen transfer efficiency (Te) is equal to the rate at which oxygen is supplied to the mixed liquor times one hundred divided by the rate at which oxygen is supplied to the aeration basins. The rate at which oxygen was supplied to the aeration basins at Trinidad was 326.5 mg/l/hr. This rate was determined from the following information: Air flow rate of 2200 cfm (determined from air flow meters), volume of aeration basins of 615,000 gallons, average air temperature of 20°C, elevation of 6,000 feet above sea level, and ratio of oxygen to air of 0.21. Using 31.1 mg/l/hr as the rate of oxygen supply to the mixed liquor and 326.5 mg/l/hr as the rate at which oxygen was supplied to the aeration basins the transfer efficiency of the aeration equipment at Trinidad was determined to be 9.53 percent.

To determine the limitations of the aeration system at Trinidad the actual rate at which oxygen was utilized by the mixed liquor were compared with the rate at which oxygen was supplied to the mixed liquor. Grab samples of mixed liquor were taken at the inlet and discharge end of the aeration basins to determine oxygen uptake rates. These oxygen uptake rates were then compared with the output of the aeration equipment. Schulze and Kooistra (1) have shown that a direct relationship exists between BOD_5 loading

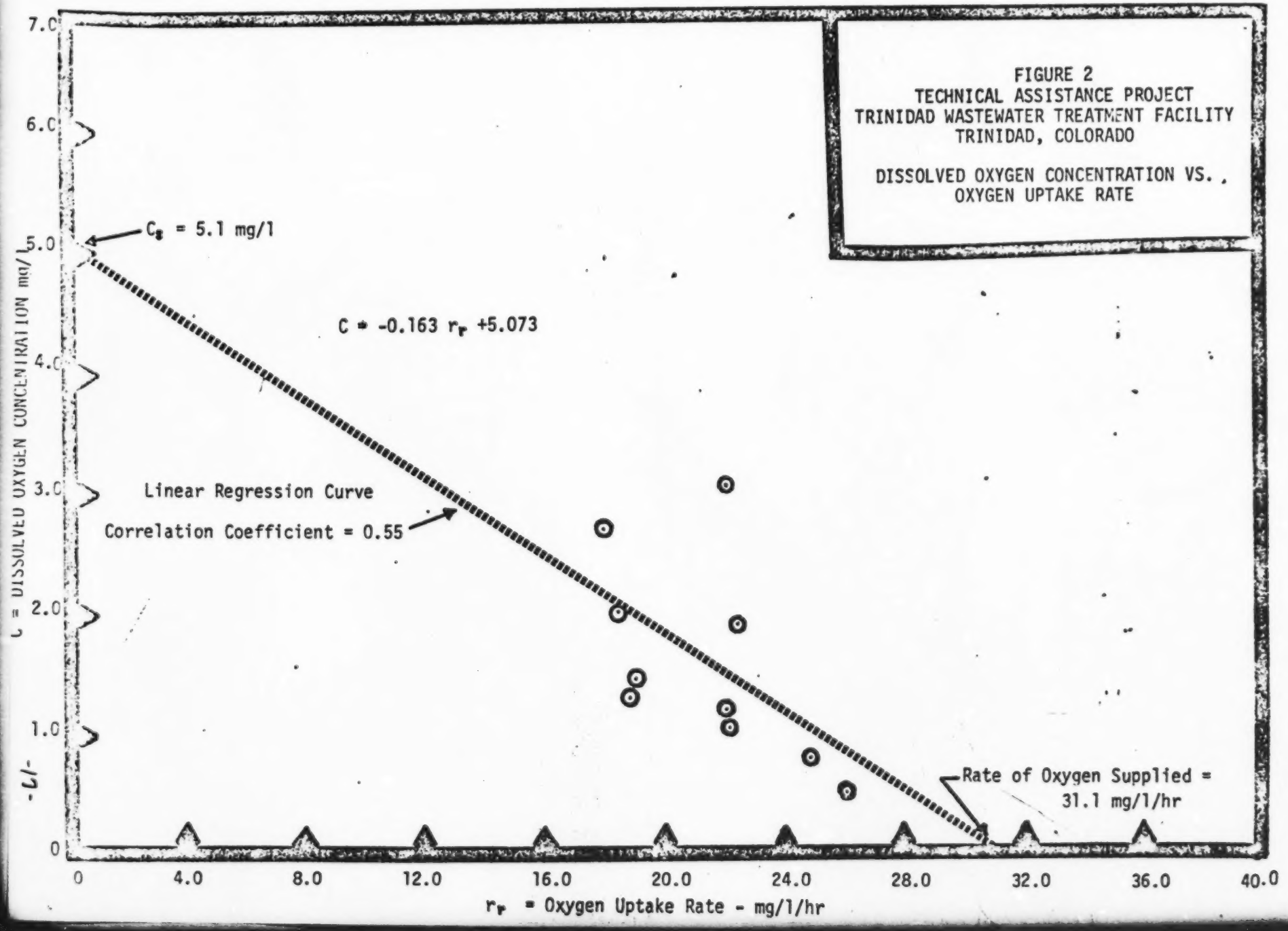
FIGURE 2
TECHNICAL ASSISTANCE PROJECT
TRINIDAD WASTEWATER TREATMENT FACILITY
TRINIDAD, COLORADO
DISSOLVED OXYGEN CONCENTRATION VS.
OXYGEN UPTAKE RATE
C_s = 5.1 mg/l
C = -0.163 r_p +5.073
Linear Regression Curve
Correlation Coefficient = 0.55
Rate of Oxygen Supplied = 31.1 mg/l/hr
C = DISSOLVED OXYGEN CONCENTRATION mg/l
r_p = Oxygen Uptake Rate - mg/l/hr
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
0
4.0
8.0
12.0
16.0
20.0
24.0
28.0
32.0
36.0
40.0

and oxygen uptake rates (i.e. the higher the BOD_5 loading the higher the oxygen uptake rate) for a given mixed liquor solids concentration. During periods of higher BOD_5 loading (i.e. higher flows) oxygen uptake rates were determined on mixed liquor samples taken from the aeration basins at Trinidad. Oxygen uptake values of 76.2 $mgO_2/l/hr$ at the inlet and 36.7 $mgO_2/l/hr$ at the discharge end of the aeration basins were determined. Respective D.O. concentrations were 0.15 mg/l and 0.2 mg/l. Conversely during periods of lower BOD_5 loadings, oxygen uptake values of 21.6 $mgO_2/l/hr$ and 22.5 $mgO_2/l/hr$ were determined at the inlet and discharge end of the aeration basins respectively. Dissolved oxygen concentrations associated with these rates were 0.30 mg/l at the inlet and 0.15 mg/l at the outlet of the basins. Based on these results it appears that the rate at which oxygen is supplied to the mixed liquor (presently 31.1 mg/l/hr) must be increased in order to satisfy the high oxygen demand during periods of higher BOD_5 loading. However, to determine the quantity of oxygen required to provide satisfactory performance at Trinidad various other parameters such as BOD_5 of the sewage, ratio of active microorganisms to MLSS concentration, as well as other parameters must be considered. A term used to interrelate these parameters is the specific oxygen uptake rate. Specific oxygen uptake rate (K_r) is equal to the oxygen uptake rate divided by the samples' corresponding suspended solids or volatile solids concentration. The BOD_5 of the sewage and the ratio of active microorganisms to MLSS concentration are the main parameters affecting the specific oxygen uptake rate. If either parameter increases, the specific oxygen uptake rate will increase. The highest specific oxygen uptake value recorded at Trinidad was 14.6 $mgO_2/gmTSS/hr$. Values as high as 65 mgO_2/gm TSS/hr have been reported in the literature. The K_r of 14.6 $mg/O_2/gmTSS/hr$ was determined from a grab sample taken at the head end of the aeration basin. To allow for an increase in BOD_5 loading and/or an increase in the ratio of active microorganisms to the MLSS concentration, a minimum K_r value of 20 $mgO_2/gmTSS/hr$ should be used to determine the oxygen requirements in the aeration basins at Trinidad.

Another important parameter affecting the quantity of oxygen required in the aeration basins is the MLSS concentration. Higher MLSS concentrations have an increased oxygen demand. For example if a specific oxygen uptake rate of 20 $mgO_2/gmTSS/hr$ is used, then the average MLSS concentration of 5700 observed during the assistance project would require an oxygen supply of 114 $mgO_2/l/hr$. However, if the MLSS concentration was decreased to 3500 mg/l (a value more typical of plants like Trinidad) the oxygen supply required would be 70 mg/l/hr.

In analyzing the oxygen requirement outlined above it is important to consider that although the higher MLSS concentration

would require more oxygen it should theoretically produce less sludge per pound of BOD_5 removed because of increased endogenous respiration. Sludge production is an important consideration because of limited digestion capacity at Trinidad.

Despite the possibility of increased sludge production, it is felt that the best alternative to be used in designing the additional oxygen supply at Trinidad is to design the oxygen supply capable of supporting a MLSS concentration of 3500 mg/l. This would require a minimum oxygen supply of 70 mg/l/hr. It is important to note that 3500 mg/l is not being recommended as the optimum MLSS concentration. The control tests will enable Trinidad personnel to determine the optimum concentration. However, it is concluded that the MLSS concentration will tend to optimize at lower MLSS concentrations than at the present MLSS concentration of 5700 mg/l. To meet the increased demand for oxygen that this analysis has shown, all alternative methods of providing additional oxygen to include using mechanical aeration equipment, increasing the capacity of the existing diffused aeration equipment, using more efficient diffusors, etc., should be investigated.

B. AEROBIC DIGESTER

A portion of the problems that were encountered with the aeration basins at Trinidad were caused by the inability to waste a desired quanity of sludge to the aerobic digester. This apparent lack of capacity was evaluated to determine the limiting portion(s) of the digestion system.

Numerous tests were made on digester contents to evaluate its performance. The dissolved oxygen concentration was always below 0.5 mg/l. Specific oxygen uptake rates (K_r) varied from 1.17 to 2.32 mgO_2/gmVSS/hr. The nitrate nitrogen concentration was less than 2 mg/l. Oxygen uptake tests conducted on the sludge wasted to the digester and on the sludge at the discharge end of the digester showed an increase in the oxygen uptake rate from 38.9 to 48.2 mg/l/hr. The total suspended solids concentration of the digester contents was approximately 20,000 mg/l of which about 63 percent were volatile. No noticeable reduction of volatile suspended solids was observed between the inlet end and discharge end of the aerobic digester. In fact the limited number of tests conducted showed a slight increase in volatile solids concentrations from the inlet to the discharge end of the digester.

In comparison, others (3) have shown that well operating aerobic digesters usually have dissolved oxygen concentrations greater than 1 mg/l; specific oxygen uptake rates less than 1 mgO_2/gmVSS/hr; nitrate nitrogen concentrations greater than 10 mg/l; and

exhibit decreases in the volatile suspended solids concentrations from the inlet to the discharge end of the digester. Results of the test conducted at Trinidad indicate a poorly operating system. The most important factors affecting the performance are the sludge detention time in the digester and the rate of oxygen supply to the digester. These aspects of the Trinidad digester are discussed below.

The required sludge detention time in an aerobic digester is dependent upon the type of treatment preceding the digester (influences the characteristics and quantity of sludge wasted to the digester) and the temperature of the sludge in the digester. However, before discussing these two items it is important to define detention time. Both the hydraulic detention time (volume of digester/volume of sludge added per day) and the solids detention time (quantity of solids in aerobic digester/quantity of solids removed from the digester per day) have been used to describe the detention time in an aerobic digester. Due to the effect of solids destruction and corresponding conversion to water, the effect of evaporation, and the effect of decanting supernatant, the solids detention time will always be greater than or equal to the hydraulic detention time. For this report all detention times discussed will be hydraulic detention times.

One of the parameters affecting the required detention in an aerobic digester is the type of treatment preceding the digester. The type of treatment preceding the digester will affect the quantity and characteristic of the sludge that is wasted. An extended aeration activated sludge process produces less sludge and a more stable sludge than a facility using the conventional activated sludge process due to increased endogenous respiration. Apparently the Trinidad facility was designed similar to the extended aeration activated sludge process since no primary clarifiers are provided. The Trinidad Wastewater Treatment Facility is operated at MLSS concentrations and loading rates (lbs BOD_5/lb VSS in system) approximating those of the extended aeration activated sludge process. A standard extended aeration system, however, not only has low loading rates, but also has a 24 hour hydraulic, sewage detention time. Both factors (detention time and loading rate) must be considered in evaluating sludge production from an activated sludge system. Goodman (2) presents S_at (MLSS concentrations times detention time) values for various activated sludge processes. Extended aeration plants have S_at values of 96,000 mg hr/l while conventional plants have S_at values of 12,000 mg hr/l. At Trinidad the hydraulic detention time of the sewage in the aeration basins at the present flow of 1 MGD and design flow of 1.5 MGD is 14.8 hr and 9.8 hr respectively. The corresponding S_at values (assuming a MLSS concentration of 3500 mg/l) are 51,800 mg hr/l and 34,600 mg hr/l respectively.

These values indicate that the Trinidad facility is not a standard extended aeration process. This fact is important because the quantity and characteristics of the sludge wasted from Trinidad are different than the quantity and characteristics of sludge wasted from an extended aeration process.

Greater quantities of sludge are wasted from Trinidad than would be wasted from a standard extended aeration process because at Trinidad sufficient solids detention time is not provided to allow endogenous respiration to proceed to the extent that respiration proceeds in the extended aeration process. In other words more endogenous respiration will occur in a true extended aeration plant (high S_at values) than at the Trinidad plant (lower S_at values). Additionally, the lower S_at values at Trinidad will cause the activated sludge that is wasted to the digester to be less stablized than the activated sludge that is wasted from an extended aeration process. Since greater quantities of less stablized sludge are produced at Trinidad, more detention time will be required in the aerobic digester.

In addition to being less stablized a portion of the sludge being wasted to the digester at Trinidad is not completely synthesized. The Trinidad Wastewater Treatment plant does not have a primary clarifier and "primary" solids are discharged directly to the secondary system. In a standard extended aeration plant adequate time is provided to convert organics in these solids to "activated" sludge by synthesis. These activated solids are then able to undergo endogenous respiration and can begin auto digestion when they are wasted to the aerobic digester. At Trinidad it appears that adequate time has not been provided to completely synthesize the "primary" solids in the secondary portion of the plant. As a result these solids must be synthesized in the aerobic digester before auto digestion can begin. (This may explain the increase in volatile suspended solids from the inlet to the outlet of the aerobic digester at Trinidad.) The effect of these solids on the design of a digester are higher oxygen demand and longer detention time requirements.

Based on the above discussion of the type of treatment preceding the aerobic digester at Trinidad it appears that increased digester detention time is necessary. In the past 15-days hydraulic detention time has been assumed to be adequate for aerobic digesters. Recently, longer times have been recommended (3,4,5,6). It has been suggested that digesters receiving primary sludge and certain types of waste activated sludge may require detention times of 20-days to greater than 30-days. An analysis was made of sludge production at Trinidad to determine

its detention time in the aerobic digester. During assistance the average daily BOD_5 load removed was 1,821 pounds with a corresponding sludge production of 1;711 pounds TSS. This can be converted to 0.94 pound TSS produced per pound of BOD_5 removed. Of this quantity of sludge produced approximately 0.4 pound TSS/pound BOD_5 removed was attributed to inert solids that enter the plant each day and 0.54 pound TSS/lb BOD_5 removed was attributed to synthesis of BOD_5 to microorganisms. To determine the portion of inert solids produced it was assumed that 30 percent of the influent suspended solids and 25 percent of the influent volatile suspended solids were biologically inert (2). The average quantity of sludge wasted to the aerobic digester each day was only 1,526 pounds since 185 pounds of the 1,711 pounds of sludge produced each day was lost in the effluent. The average volume wasted was 8,900 gallons at a concentration of 20,550 mg/l. The aerobic digester detention time at this wasting rate was 12.6 days. It is noted that return sludge rates had been intentionally decreased to obtain a higher solids concentration in the waste sludge flow. Under normal operating conditions a return sludge concentration of 10,000 mg/l to 15,000 mg/l would be expected. Assuming a concentration of 12,500 mg/l, the volume of sludge that would have to be wasted each day would increase from 8,900 gallons to 14,600 gallons and the detention time would decrease from 12.6 days to 7.7 days.

Assuming that present influent BOD_5 and TSS concentration will remain the same at the design flow of 1.5 MGD a prediction of digester detention time at design can be made. The quantity of sludge produced each day would be approximately 2560 pounds of which 2,280 pounds would be wasted to the digester each day. It is assumed that 280 pounds of sludge would be lost as suspended solids in the effluent each day. If a concentration of 12,500 mg/l TSS is assumed then the volume of sludge wasted each day would be 21,900 gallons and the detention time in the aerobic digester would be only 5.1 days.

Based on a minimum 20-day detention time and the solids production as outlined above (at 12,500 mg/l MLSS) it appears that the volume of the aerobic digester should be increased approximately 3 times its present volume at the present flow and influent BOD_5 and TSS concentrations. At the design flow of 1.5 MGD the volume of the aerobic digester should be increased approximately 4 times. The corresponding detention times in the aerobic digester that would result from these increases would be 23.1 days for the 1 MGD flow and 20.4 days for a 1.5 MGD flow. These detention times are within the range of recommended values discussed earlier in the report. However, the effect of temperature on biological activity must also be included in determining digester detention time.

The effects of temperature on the operation and performance of the aerobic digester were discussed with the plant operators at Trinidad after the termination of the assistance project. The temperature of the sludge in the digester dropped to 11°C and below. At these low temperatures the sludge would not decant and at the same time the D.O. concentration in the aerobic digester began to increase from less than 0.5 mg/l to greater than 3 mg/l. These conditions indicate that the rate of biological activity had decreased significantly as the sludge temperature decreased. The decreased rate of biological activity due to low temperature has been recognized and discussed in the literature (3,4,6). For temperatures less than 15°C additional detention time in the aerobic digester has been recommended (i.e. 5-10-days). Considering the effect of the temperatures encountered at Trinidad and the type of sludge wasted to the aerobic digester, a minimum sludge detention time in the aerobic digester of 25-days is recommended. At the present plant flow (1 MGD) the volume of the digester should be 48,800 ft^3 (assume volume wasted of 14,600 gallons/day at a concentration of 12,500 mg/l), and at the design flow (1.5 MGD) the volume of the digester should be 73,300 ft^3 (assume volume wasted of 21,900 gallons/day at a concentration of 12,500 mg/l). Somewhat smaller volumes may be acceptable if the detention time is based on solids retention time in the aerobic digester or the temperature of the sludge in the aerobic digester is kept at a minimum temperature of 15°C.

Extreme low temperatures in the aerobic digester may be partially alleviated by providing an earthen embankment around the exposed sides of the digester, insulating the air header, and providing a cover with adjustable openings over the top of the digester. Adjustable openings on the cover are necessary to prevent extreme increases in temperature during the summer months.

From the Engineering report entitled "Design Analysis of Sewage Treatment Plant, Trinidad, Colorado" the aerobic digester was sized using the following criteria: continuous flow of waste sludge through the digester, 5-day detention time for total organics in raw sewage per day, 2 percent solids content in digester (i.e. 2 percent waste sludge concentration), 300 mg/l total organics in raw sewage, and 0.55 lb waste solids/lb raw BOD. Based on these criteria the design volume of the aerobic digester was 15,000 ft^3 (7).

The other important factor that appeared to be affecting the performance of Trinidad's aerobic digester was the rate of oxygen supply. Oxygen was supplied to the aerobic digesters at a rate equal to 27.6 mg/l/hr. (All diffusors in the aerobic digester had been cleaned just prior to the assistance project.) This rate was determined by using a diffusor transfer efficiency (Te) of 9.53 percent (the same Te determined for the diffusors in the

aeration basins), and air flow rate of 330 cfm (obtained from and air flow meter), and average air temperature of 20°C, an elevation of 6,000 ft above sea level, a ratio of oxygen to air of 0.21, and a volume of the digester of 104,000 gallons. The volume of each hopper in the digester is 16,000 gallons. However, the #7 hopper is aerated only 12 hours per day, thus, the effective volume of the digester was assumed to be only 6.5 times 16,000 gallons or 104,000 gallons.

Oxygen uptake rates (r_r) in the aerobic digester at Trinidad varied from 38.9 mg/l/hr to 48.2 mg/l/hr. The corresponding specific oxygen uptake rate (K_r) varied from 1.86 mgO_2/gmTSS/hr to 2.31 mgO_2/gmTSS/hr. Specific oxygen uptake rates ranging from 0.5 mgO_2/gmVSS/hr to 6.3 mgO_2/gmVSS/hr or 0.32 mgO_2/gmTSS/hr to 3.97 mgO_2/gmTSS/hr (assume ratio of VSS to TSS equal to the ratio at Trinidad or 0.63) have been reported (3). The lower specific oxygen uptake values are associated with digestion of sludge that is more completely stablized at the time it is wasted to the digester (e.g. sludge from an extended aeration process). The higher specific oxygen uptake values are associated with digestion of sludge that require synthesis before stablization can proceed (e.g. sludge from a primary clarifier). For these reasons it is assumed that a minimum specific oxygen uptake rate of 3 mgO_2/gmTSS/hr would be satisfactory in determining the quantity of oxygen required in the aerobic digester at Trinidad. At a TSS concentration of 20,000 mg/l the minimum quantity of oxygen required is 60 mg/l/hr. This is slightly over twice the available supply (27.6 mg/l/hr). As was the case with the aeration basins, it is suggested that alternative methods to include mechanical aeration equipment, increasing capacity of the existing diffused aeration equipment, using more efficient diffusors, etc., should be investigated when designing to meet the increased oxygen demand indicated by the studies at Trinidad.

IV. SUMMARY AND CONCLUSIONS

The Trinidad technical assistance project was initiated in order to develop better analytical capabilities for closer monitoring and control of wastewater treatment operations. In addition those portions of the plant which limited improvement of effluent quality or hindered operation of the sludge digestion unit were identified and evaluated.

Plant personnel were taught the procedures used in conducting the BOD_5, total suspended solids, and volatile suspended solids analysis. In addition training was given on the use of the dissolved oxygen meter. As a result of this assistance, these tests are now being performed routinely by plant personnel.

In addition to the instruction in conducting analytical

analysis used to monitor plant performance, plant personnel were given instruction in conducting and interpreting various control tests. Dissolved oxygen tests, centrifuge tests, turbidity, settleability tests and sludge blanket depth were the control tests that were initiated. Plant personnel are continuing to use these control tests to adjust plant operations in order to consistently produce the best possible effluent with the facilities available.

At Trinidad initiation of the control tests, corresponding data interpretation, and methods used to control plant operations pointed out various operational procedures that should be followed. In addition, specific plant limitations which hindered control flexibility or hindered operation and maintenance were identified.

A maintenance problem is encountered when trying to service the comminutor. Although the operators can divert sewage through a bar screen and bypass the comminutor the diverted sewage reenters the main channel directly behind the comminutor thereby flooding the area the operator has to work in. A special gate to block the sewage from entering this working area or a different bypassing arrangement will have to be constructed before the operator can easily service or repair the comminutor.

Obtaining an even solids distribution between the two aeration basins was difficult to achieve and presented operational problems. Return sludge flow is not completely mixed with sewage flow prior to entry into the aeration basins and the MLSS concentration in the aeration basins vary. Plant personnel placed an adjustable splitter box between the return sludge stream and sewage stream to provide better mixing conditions. The adjustable splitter box served to alleviate some of the problem, however, difficulties in balancing the MLSS concentration in the aeration basins are still encountered when the return sludge flow rate is varied. Modification should be made to the return sludge flow piping to either introduce return sludge further upstream in the sewage channel to insure that complete mixing is provided before the combined flow enters the aeration basins or introduce return sludge separately and equally to each aeration basin.

Another operation problem is one of convenient return sludge flow control. Prior to assistance return sludge flow was adjusted by opening or closing a gate valve. Problems with rags and other debris clogging the opening in the gate valve occurred when attempts were made to reduce return sludge flow. To prevent clogging the gate valve had been opened wide enough to pass the rags and a constant return sludge flow rate had been established and was maintained. During assistance return sludge flow was adjusted by opening or closing a plug valve located in the return sludge pump house. No problems with clogging occurred. However, the location of the plug valve made return sludge flow control practices difficult. To make return sludge flow control practices less

difficult, a plug valve or butterfly valve should be located near the return sludge flow measuring device which is located near the inlet to the aeration basins.

A problem was also encountered at Trinidad with the four-inch proportional weir that is used to measure the flow to the aerobic digester. At a gauge depth of 0.2 feet the actual flow passing through the four-inch proportional weir was measured to be approximately 78gpm. According to the flow chart provided by the operators the flow should have been 60gpm. (It may be expected that the actual flow rate through the proportional weir that is used to measure return sludge flow is not equal to the flow rate obtained from it's weir table also.) Although day-to-day comparisons can be made using the existing proportional weirs, it is suggested that consideration be given to installing more accurate flow measuring devices.

No flexibility for activated sludge process variations have been provided at the Trinidad facility. Return sludge flow mixes with sewage flow and the combined flow enters the head end of the aeration basins. It appears that with minor modifications the capability of "step loading" the sewage to the aeration basins may be incorporated. The step loading mode of operation provides for a more even distribution of oxygen requirements throughout the entire length of the aeration basins and increases the mean MLSS concentration for a given solids loading to the clarifier. The minor modifications that may allow the step loading capability are: using the center channel located between the two aeration basins as a distribution channel and locating gates along the channel for sewage distribution to the aeration basins.

Another area of operation difficulty which was significant in hindering plant operation and control was the amount of air supplied to the aeration basins. During the survey the dissolved oxygen concentration in the aeration basins was usually less than 0.5 mg/l. To insure that the aeration system was providing maximum oxygen transfer, the diffusors in the aeration basins were inspected and found to be approximately 20 percent clogged. A program was initiated to clean all diffusors in the aeration basins. At the terminiation of assistance approximately one-half of all diffusors in the aeration basins had been cleaned. Since then all diffusors in the aeration basins have been cleaned. It is recommended that all diffusors in the aeration basins and aerobic digester be placed on a routine maintenance schedule and cleaned a minimum of three times per year.

Cleaning the diffusors did not measurably increase the D.O. concentration in the aeration basins. In a further effort to increase D.O. concentration an attempt was made to increase the air flow rate to the aeration basins. Three 1200 cfm air

compressors were used to force air to the aeration basins and aerobic digester. However, when all three compressors were on, back pressure in the system caused the safety pressure relief valves to open. Since the termination of the assistance project all diffusors in the aeration basin were cleaned and fully opened and a successful attempt was made to use all three 1200 cfm air compressors. However, the D.O. concentration in the aeration basin still did not increase significantly.

Another approach to increase D.O. concentration in the aeration basins consisted of decreasing the MLSS concentration. The maximum quantity of sludge was wasted with facilities available in that return sludge flow was decreased when plant flow increased in order to increase the waste sludge concentration. In so doing wasting was more effective (i.e. more solids were wasted with the same volume of flow). Daily tests results of the mixed liquor concentration and depth of blanket in the final clarifier showed that the quantity of activated sludge in the system did not increase nor decrease significantly. This indicated that the quantity of sludge wasted each day was approximately equal to the quantity of sludge produced each day and that even with plant operation distorted (i.e. decrease return sludge flow when plant flow increases) plant limitations would not allow desired operating conditions to be achieved.

Another factor which influences plant operation is manpower requirements versus manpower supply. During assistance Trinidad used three operators to operate and maintain the plant as well as perform the analytical tests necessary to monitor plant performance. All three operators have comparable training and no specific operator was in-charge of the entire plant operation. It is recommended that a separate laboratory technician be used 5-days per week to perform the analytical tests necessary to monitor plant performance. This would allow the plant operators to concentrate on plant operation and maintenance. Secondly, it is recommended that a chief operator working at the plant be appointed. This would allow one person to direct all control, maintenance, and monitoring activities and make and monitor appropriate changes in the mode of plant operation in order to determine the mode of operation which yields the most consistent, best possible effluent.

Plant effluent quality was generally satisfactory. During assistance the average effluent BOD_5 and TSS concentrations were approximately 20 mg/l. However, it is felt that this BOD_5 and TSS concentration would be significantly decreased if specific plant limitations are overcome.

One of the significant limitations at the Trinidad facility was the lack of an adequate dissolved oxygen concentration in the

aeration basins. An analysis of the performance of the aeration basins was undertaken by conducting a series of special studies including determination of the transfer efficiency of the course bubble diffusors and limitations of the aeration equipment in the aeration basins. The transfer efficiency of the course bubble diffusor was determined to be 9.53 percent. To determine the limitations of the aeration system, the actual rate at which oxygen was utilized by the mixed liquor was compared with the rate at which oxygen was supplied to the mixed liquor. The rate at which oxygen was supplied to the mixed liquor was determined to be 31.1 mg/l/hr. On grab samples of mixed liquor the maximum rate at which oxygen was utilized was 76.2 mg/l/hr. The corresponding specific oxygen uptake rate (K_r) was 14.6 mgO_2/gmTSS/hr. Based on this Kr result and Kr values recorded in the literature, a minimum Kr of 20 mgO_2/gmTSS/hr is recommended for determining the quantity of oxygen required in the aeration basins at Trinidad.

Since a minimum Kr has been established (20 mgO_2/gmTSS/hr), the other important parameter affecting the quantity of oxygen required in the aeration basins is the MLSS concentration. It is recommended that the oxygen supply be designed to support a MLSS concentration of 3500 mg/l. This would require a minimum oxygen supply of 70 mg/l/hr (an increase of slightly over twice the present supply). All alternative methods of providing additional oxygen to include using mechanical aeration equipment, increasing capability of the existing diffused aeration equipment, using more efficient diffusors, etc., should be investigated.

A portion of the problems that were encountered with the aeration basins at Trinidad were caused by the inability to waste the desired quantity of sludge to the aerobic digester. This apparent lack of capacity was evaluated to determine the limiting portion(s) of the digestion system. Numerous tests were taken on the digester contents to evaluate its performance. These results were compared with corresponding results from digesters that were performing satisfactorily. The comparisons indicated that the digester at Trinidad was not performing satisfactorily. The two most important parameters affecting the performance of the aerobic digester at Trinidad were detention time and rate of oxygen supply.

The required sludge detention time in an aerobic digester is dependent upon the type of treatment precedingthe digester and the temperature of sludge in the digester. At Trinidad the type of treatment preceding the digester is similar to the extended aeration variation of the activated sludge process. The Trinidad plant is operated at MLSS concentrations and loading rates approximating those of the extended aeration process, however the hydraulic, sewage detention time at Trinidad is less than the hydraulic, sewage

detention time normally found in the extended aeration process. Thus, the Trinidad facility is not a standard extended aeration process and the quantity and characteristics of the sludge wasted from the Trinidad facility are not similar to the quantity and characteristics of the sludge wasted from an extended aeration process. Greater quantities of less stablized sludge were encountered at Trinidad because sufficient solids detention time was not provided to allow endogenous respiration to proceed to the extent that respiration proceeds in the extended aeration process. In addition to being less stablized a portion of the sludge being wasted to the digester at Trinidad was not completely synthesized. Trinidad does not have a primary clarifier and "primary" solids are discharged directly to the secondary system. Sufficient time is not provided in the secondary system for complete synthesis of these solids, therefore, synthesis must take place in the digester. The effect of the greater quantity of less stablized sludge plus solids that requires further synthesis on the design of a digester are longer detention time and higher oxygen supply requirements.

The quantity of sludge produced at Trinidad was evaluated to determine its detention time in the aerobic digester. The detention times in the digester was determined to be 7.7 days under present conditions. At the design flow of 1.5 MGD the detention time was predicted to be 5.1 days.

The recommended aerobic digester detention time for satisfactory digestion of the type of sludge wasted at Trinidad is 20-days to 30-days. However, the effect of temperature on biological activity must also be included in determining the digester detention time. After the termination of the assistance project decreased temperatures of the sludge in the aerobic digester at Trinidad caused the dissolved oxygen concentration of the sludge to increase to greater than 3 mg/l. In addition the sludge solids would not separate from the liquid and the operators were not able to supernate. These characteristics of the sludge indicate that the rate of biological activity within the sludge had decreased significantly. These low temperatures of aerobic digester sludges may be avoided by building an earthen embankment around the exposed sides of the digester, insulating the air header, and providing a cover with adjustable openings over the top of the digester.

Allowing for the lower sludge temperatures encountered during winter operation at Trinidad and the recommended detention times from the literature, it is assumed that a minimum hydraulic detention time of 25-days would be satisfactory for determining the

required size of the aerobic digester. Under normal operating procedures and at the present sludge yield of 0.94 pound TSS/pound BOD_5 removed, the volume of the aerobic digester should be 48,800 ft^3 at present flow rates and 73,300 ft^3 at the design flow rate of 1.5 MGD. The present digester capacity is 15,000 ft^3. Somewhat smaller volumes may be acceptable if the detention time is based on solids retention time in the aerobic digester or the sludge temperature in the digester is maintained at a minimum temperature of 15°C.

The other important factor that appeared to be affecting the performance of Trinidad's aerobic digester was the rate of oxygen supply. Oxygen was supplied to the aerobic digester at a rate of 27.6 mg/l/hr. From grab samples taken of the aerobic digester sludge the maximum rate at which oxygen was utilized by the sludge was 48.2 mg/l/hr. The corresponding Kr was 2.31 mgO_2/gmTSS/hr. Based on this Kr result and Kr values recorded in the literature it is recommended that a Kr of 3 mgO_2/gmTSS/hr be used in determining the quantity of oxygen required in the aerobic digester at Trinidad. At an aerobic digester sludge concentration of 20,000 mg/l the recommended minimum oxygen supply is 60 mg/l/hr. This is slightly over twice the rate at which oxygen is presently supplied (27.6 mg/l/hr). Since major plant modifications appear to be necessary all alternative methods to achieve satisfactory plant operation and performance should be considered.

VII. RECOMMENDATIONS

The following recommendations are made:

1. Reconstruct or alter the influent channel to provide the operators a dry work area in which to repair or maintain the comminutor.

2. Return sludge flow should be introduced to the sewage stream and completely mixed with the sewage before entry into the aeration basins, or, introduced equally and separately into each aeration basin to insure equal solids distribution between the aeration basins.

3. Place a plug or butterfly valve near the return sludge flow measuring device which is located near the inlet to the aeration basins to facilitate operation.

4. Consideration should be given to installing more accurate flow measuring devices in place of the proportional weirs that are presently being used for flow measurement purposes.

5. Modifications should be made to the inlet channel of the aeration basins to provide step loading flexibility in addition to the existing plug flow mode of operation.

6. All air diffusors in the aeration basins and aerobic digester should be placed on a maintenance schedule and cleaned a minimum of 3 times per year.

7. Methods of operational control and control testing procedures outlined during the assistance project should be continued.

8. A separate laboratory technician should be used to perform the analytical work necessary to monitor plant performance.

9. A chief operator working at the plant should be appointed.

10. A minimum of 70 mg/l/hr of oxygen be supplied to the mixed liquor in the aeration basins.

11. A minimum of 60 mg/l/hr of oxygen be supplied to the sludge in the aerobic digester.

12. The minimum detention time in the aerobic digester should be 25-days. At present plant flow of 1 MGD the corresponding volume of the digester should be 48,800 ft^3 at design flow of 1.5 MGD the volume of the digester should be 73,300 ft^3. Somewhat smaller volumes may be acceptable if the detention time is based on solids retention time in the aerobic digester or the sludge temperature in the digester is maintained at a minimum temperature of 15°C.

13. The aerobic digester at Trinidad should be provided with an earthen embankment around the exposed sides, insulated air header, and cover with adjustable openings over the top of the digester.

14. All alternative methods to achieve satisfactory plant operation and performance should be considered.

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